REMOTE SENSING CENTRE

1984 MANITOBA REMOTE SENSING CROP AREA ESTIMATION PROJECT

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1984 Manitoba Remote Sensing

Crop Area Estimation

Project

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1. INTRODUCTION

1.1 BACKGROUND

In 1983, a Remote Sensing Crop Area Estimation Project was undertaken in Manitoba Crop Districts 1, 2 and 3 under the Federal/Provincial Technology Enhancement Program. This project involved a cooperative effort between the Canada Centre for Remote Sensing (CCRS), Manitoba Department of Agriculture (MDA), Manitoba Remote Sensing Centre (MRSC) and Statistics Canada (SC). The 1983 Project provided evidence that reliable estimates for canola/rapeseed, grains[1] and fallow could be achieved through remote sensing techniques (L. Horn, R.A. Ryerson, C. Thibault, R. Dobbins 1984). The 1983 Manitoba Crop Area Estimation Project report provides detailed information on the project.

In 1984, this cooperative project was significantly expanded to encompass all of agro-Manitoba. The Canada Centre for Remote Sensing, Manitoba Department of Agriculture, Manitoba Remote Sensing Centre, and Statistics Canada acted as the participatory agencies in the 1984 project.

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1 - The grains class includes spring wheat, oats, barley, spring rye and mixed grain.

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1.2 GOALS

Because the 1984 Manitoba Crop Area Estimation Project was the first real-time, full-scale, multi-crop project ever undertaken, many primary and secondary goals were set.

Primary Goals:

1. To generate accurate real-time area estimates for canola/rapeseed, summerfallow and grain areas on a sub-provincial area (SPA) basis based on National Farm Survey (NFS) ground data.

Secondary Goals:

1. To generate statistics for small areas, (crop districts, and rural municipalities) using remote sensing techniques.

2. To test the classification of specialty crops. Such crops would include potatoes, buckwheat, canary seed, grain corn, faba beans, field beans, soybeans, field peas, sugar beets, lentils, mustard seed, and sunflowers.

3. To assess the use of soil-related criteria in remote sensing sampling design.

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The secondary goals of this project, for the most part, would be sought after the primary objectives had been realized, and the real-time portion of the project completed.

1.3 APPROACH

The project was divided into separate tasks and each task was alloted to the workstation holding the comparative advantage in expertise. Signature development and classification stages were completed at MRSC; their knowledge of and familiarity with agricultural Manitoba was a valuable asset in the image analysis portion of the project -- especially in analysing marginal areas. As well, field checks were possible for the Winnipeg team as most segments were within reasonable driving distance of the Manitoba Remote Sensing Centre Office.

Simultaneous to signature development in Winnipeg, Ottawa analysts began to delineate segment, enumerative area (EA), and crop district boundaries and form them into theme files for use in this and future projects. The boundary establishment began in Ottawa during June and continued throughout the project.

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The remote sensing technical team based in Ottawa was responsible for extracting statistics from the segments and sub-provincial areas (SPA's) classified in Winnipeg. This information was then forwarded to Statistics Canada methodologists for regression analysis.

1.4 STUDY AREA

The area of interest for the 1984 Crop Area Estimation Project included all twelve Manitoba crop districts; these crop districts were arranged into six sub-provincial areas. Figure I indicates the location and distribution of the SPA's, and outlines the study area. LANDSAT coverage of the six SPA's would be achieved with eight LANDSAT computer compatible tape (CCT) frames.

1.5 PROJECT MANAGEMENT AND COMMUNICATION

Cooperative projects among several agencies can benefit from a large pool of expertise. Such was the case with the 1984 Manitoba Crop Area Estimation Project. The survey sampling, statistical and remote sensing expertise of Statistics Canada were complemented by the remote sensing skills and local knowledge of the Manitoba Remote Sensing Centre and the awareness of agricultural conditions of Manitoba Agriculture. Each agency played a significant role in the project, resulting in a synergistic effect.

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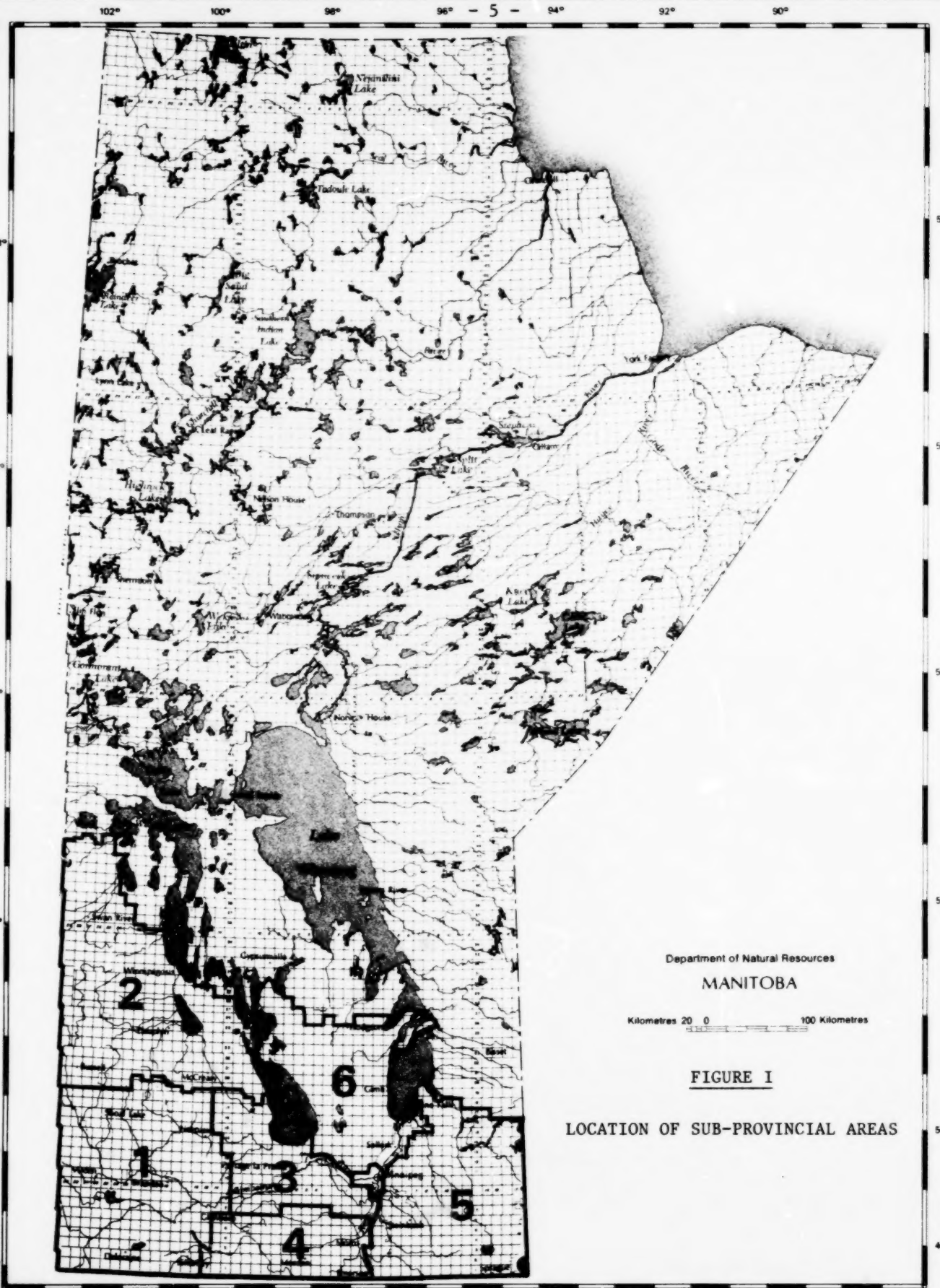

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Kilometres 20 0 100 Kilometres

FIGURE I

LOCATION OF SUB-PROVINCIAL AREAS

While increasing the number of agencies involved in such a project increases the expertise available, it requires a greater effort in coordination and communication to achieve optimal results. In this project, the distance between agencies, as well as the number of agencies participating created a challenge. It is essential that all participating agencies be involved in the project planning process and be kept aware of developments throughout the project. Proposals submitted for the project were reviewed and revised by all participating agencies. Later, a meeting at which all agencies were represented, was held to confirm the proposal. Once the project began, informal telephone contact as well as more formal monthly newsletters kept all parties aware of procedures, progress and problems. In addition, a member of the Statistics Canada remote sensing technical team was located at the Manitoba Centre for Remote Sensing for the duration of the project.

2. METHODS

2.1 NATIONAL FARM SURVEY DESIGN

The National Farm Survey is an agricultural survey conducted annually by Statistics Canada to provide a variety of agricultural information on a provincial basis. Part of this information is used as the ground data for remote sensing crop area estimation projects.

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Farms enumerated in the NFS are either randomly chosen by area, or specifically chosen because of their relatively large size with regard to total cattle, total pigs, total cropland or total sales. The area component of the selection identifies "segments" to be enumerated. These segments usually measure three square miles, and all farmers operating any land within the segment are enumerated. In 1984, two hundred and eighty segments were selected and enumerated in agricultural areas of Manitoba.

2.2 ACQUISITION OF GROUND REFERENCE DATA

The remote sensing project team is interested in that part of the NFS interview from which ground data is obtained. Enumerators, equipped with enlarged segment air photos, ask each farm operator to identify the fields he/she operates, indicate the crops grown and field acreages. This information is recorded on the air photo and used by the image analyst during the real-time project. The photos indicate fields for use as training sites (in developing the spectral signature of the crops in question) and are used, along with LANDSAT measurements, as the basis for the regression from which estimates are generated.

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2.3 ACQUISITION OF IMAGERY

The target region for the area estimation project was the twelve crop districts in Manitoba. The region required eight LANDSAT CCT frames for full coverage. Table I indicates the Tracks, Frames and Offsets required for the project. The convention adopted for assigning three-character tape names involved choosing the largest community in the frame and shortening its name to three letters. This method also gave a geographic picture to the frame by referring to its name.

Table I

Manitoba Project LANDSAT Tape Requirements

Track	Frame	Offset	Designated Name
30	25	12.0 seconds	TRA (Transcona)
31	24	17.4 seconds	ARB (Arbourg)
31	25	14.5 seconds	WPG (Winnipeg)
32	24	14.3 seconds	NAR (The Narrows)
32	25	13.3 seconds	POR (Portage la Prairie)
33	24	10.3 seconds	DAU (Dauphin)
33	25	11.3 seconds	BRA (Brandon)
34	23	19.7 seconds	MIN (Minnedosa)

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With the launch of LANDSAT V on March 1, 1984, commencement of tracking in mid-April, and the continued tracking of LANDSAT IV, eight-day coverage of Manitoba was available during the project. Even with this intense coverage of the study area, clouds were a major impediment to data acquisition. Of the eight desired images, only four were adequate in terms of cloud cover and tracking date. Figure II and its related table show the acquired LANDSAT data in terms of position and date.

Imagery attained from LANDSAT IV was adjusted with calibration 3, while that from LANDSAT V was subjected to calibration 2 corrections. All imagery was corrected for mirror velocity and earth rotation factors.

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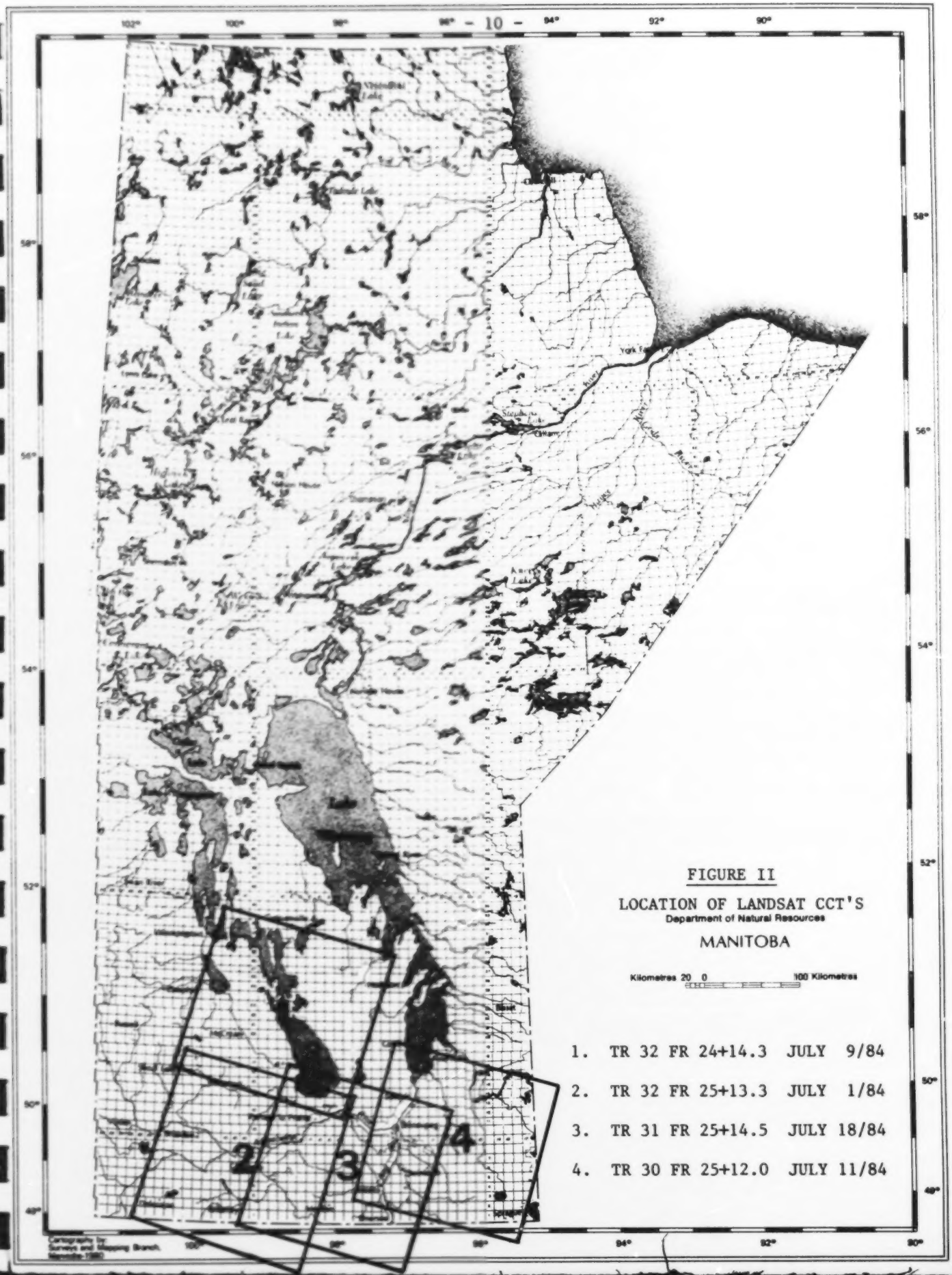

FIGURE II

LOCATION OF LANDSAT CCT'S

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Kilometres 20 0 100 Kilometres

1. TR 32 FR 24+14.3 JULY 9/84
2. TR 32 FR 25+13.3 JULY 1/84
3. TR 31 FR 25+14.5 JULY 18/84
4. TR 30 FR 25+12.0 JULY 11/84

Prior to the project, the optimal biological window for canola/rapeseed was projected to be July 29th to August 4th, plus or minus one week. Crop and weather information, however, indicated that the 1984 crop would dictate an earlier biological window. Weekly Crop Reports produced by the Agriculture Statistics Branch of Manitoba Agriculture indicated that during the week prior to July 10, much of Manitoba's canola/rapeseed was over 60% in bloom. Acquired image dates ranged from July 1 to July 18. It may be noted that the July 1 image, which covered an area over Portage and Brandon, did not exemplify characteristic consistency of flowering within or between canola fields; however, separability of canola from other cover types was still achieved.

2.4 IMAGE ANALYSIS PROCEDURES

2.4.1 Introduction

Computer analysis of the satellite data was performed on an ARIES II image analysis system using AIIASP software. Because of magnitude, scope and time constraints, the image analysis procedures were shared between the Manitoba Remote Sensing Centre and Statistics Canada in Ottawa.

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The concept of automated land cover classifications from LANDSAT data involves "training" the computer to recognize spectral responses of the target cover types and subsequently having the computer sort the picture elements (pixels) into similar groups based on these spectral attributes. Within this classification process, misclassification of pixels may occur as a result of spectral similarities between crop types or lack of enough spectral variations of the same crop type in the training area selection process. These errors are either errors of omission or commission.

2.4.2 Distribution of Workload

Because of the magnitude of the project (crop area estimates for all of agro-Manitoba) coupled with a September 7, 1984 deadline for statistical analysis, careful consideration was given to workload distribution. The project contained three major components: 1. administration, 2. image classification, and 3. statistical analysis. The administrative component was equally shared by Manitoba and Statistics Canada in Ottawa. The image classification component was largely conducted in Manitoba; this took advantage of local knowledge of crop conditions and distribution. An analyst from SC also aided in the image classification process. The statistical analysis component was conducted by Statistics Canada. More detail on these aspects will follow in subsequent sections.

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2.4.3 Approach

A linear regression technique was used to derive accurate crop area estimates (Horn et. al. 1983). The technique involved the use of 280 ground segments distributed throughout agro-Manitoba. These ground segments were used in the classification training process and supplied data for the linear regressions. Each LANDSAT computer tape was classified for the target cover types. After the classification was complete, the results of the classification within the segments were compared to the actual area figures which represent the "real world". These two variables were the basis for the linear regression calculations. The linear regression estimator, which was coupled with stratification and weighting techniques, was then used to adjust the crop area estimate for the entire LANDSAT scene by crop district.

2.4.4 Boundary Formation on Archival Imagery

To produce crop area statistics using the NFS design, remote sensing measurements must be obtained on a segment and sub-provincial area basis. Also, enumerative area data are used in the classification assessment analysis phase for comparison with 1981 Census numbers. To facilitate the segment location and classification process during the critical period, and to allow for classification assessment

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analysis and statistics extraction, all ground segment, crop district and enumerative area boundaries were pre-drawn on an archival LANDSAT data set using 1983 imagery. The archival LANDSAT data set was ordered with the same offsets for each scene as the tapes used for classification.

The process involved a number of steps:

a) Locating the Target: By referring to maps and the DIPIX loaded LANDSAT image, target boundaries (generally natural boundaries; i.e., roads, waterbodies, etc.) were located.

b) Establishing and Saving the Boundary: Using the DIPIX system's outlining capabilites, boundaries were drawn onto the loaded image. The boundaries were then saved on disk.

c) Generating Theme Files and Checking: This task was undertaken so that boundaries could be adapted to overlay images. This was basically a computer procedure to transform the format of the files.

The execution of these steps, including both image analysis and computer processing time, accounted for approximately 50 hours per tape. It should be noted that this is a one-time procedure. Subsequent maintenance/update work, which would account for the 25% segment rotation system should require less than four hours per tape (per year).

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Table II indicates average outlining and processing time per unit, units per tape, time per tape, and files created per tape.

Table II

Computer Interactive Image Analysis Time[1] Per Unit and Per Tape in the Boundary Formation Procedure

Unit	Average Locating/ Outlining Time Per Unit	Average Saving Time Per Unit	Average Number of Units Per Tape	Average Total Time per Tape	Average Number of Files Created Per Tape
Segment	7 min.	4 min.	35	6 1/2 hrs	40
Enumerative Area (EA)	4 min.	4 min.	150	20 hrs	150
Sub-provincial Area (SPA)				15 hrs	1
Tasks					
Manual Theme				10 hrs	2

1 - Does not equal C.P.U. time.

Once the boundary drawing had been completed, the classification theme file for each new image was resampled to match the coordinate system of its respective archival image. This was accomplished using a second order polynomial transform algorithm and a nearest neighbour resampling procedure. After the resampling was complete, previously drawn boundary lines could be called up and displayed over-top of the classification lines, thus permitting area calculations to be performed.

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2.4.5 Preparation for Analysis

Step 1: The main objectives of the preparation stage were to load the satellite data onto disk, examine the image for quality and determine which ground segments were contained on the image. Each image was also examined for striping, dropped lines, and pixel registrations. At this stage the image was also assigned a unique three character area name to which all of that tape's files would be related.

Step 2: Locating line/pixel coordinates of the ground segments on the imagery and recording them on a base map was completed for reference later in the interactive training program.

2.4.6 Signature Development and Classification

The main objectives of the image analysis phase were to select pure training areas representing each cover class of interest, create the necessary signature files and classify the image. Before the interactive training commenced, each image was classified using a real-time, quick parallelepiped classifier. This was done to evaluate how the data would cluster and classify using the given ground reference data.

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The interactive training program was used to define and purify training areas, and the statistics generation program was used to examine training area "purity" by looking at scattergrams. The ground reference data played a critical role during this phase as it provided the basis for interpreting the satellite data.

Under the interactive training program, a subscene of 721 lines by 721 pixels containing segment data was displayed on the television monitor as a two feature image. Only two satellite bands (numbers 5 and 7) were displayed because of a limitation of 15 bits of video memory which must be partitioned to image features and training areas which are to be drawn.

Ground segment photo mosaics (prepared by National Farm Survey enumerators) showing the land cover types, areas and locations, were used to select fields for training sites. Many fields, all of the same crop type, were drawn from segments scattered throughout the image. It is essential to choose variations of each crop in order to account for spectral variation due to date of seeding, fertilizer application rates, soil types, and moisture conditions.

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Even though extreme care is taken in outlining training area fields, invariably, "foreign" pixels will be contained in the data set. If left in the training data set, these foreign pixels may cause spurious classification results. These may be removed by training area purification.

The image analysis system sorts pixels into respective cover types according to their spectral signatures. Spectral signature files for each training set were calculated from the digital values in all four bands of LANDSAT. The process of assessing training areas to determine their suitability before signatures are generated is enhanced by viewing a scattergram of band 5 versus band 7; this gives a good indication of training area purity. Confusion between classes can be expected whenever two spectral clusters meet or overlap.

The purified training areas and their respective signatures were used as input into the maximum likelihood classification program. This program was run in batch mode and required 3 - 6 hours of processing time. All interactive training and signature generation processes took place during day shifts, while batch processing occurred during evening hours.

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Results of the first classification were inspected for accuracy. Comparisons were made between the classified results and the ground segment data. Special attention was paid to areas of unclassified cropland and those fields which were being confused with another crop. To correct these inconsistencies, new training areas were added to incorporate pixels from the unclassified fields, while other training areas were further purified to help eliminate confusion. When all retraining and signature modification was complete, another supervised classification was run. Re-examination of the second classification determed whether a third iteration was required.

2.4.7 Post Classification Analysis

Assessment of the classified results for accuracy involved the identification of problem segments following image processing.

Significant differences between the satellite and recorded NFS survey data were noted. Occasionally, ground segments had to be revisited in the field to account for anomalies on the photo mosaic of the segment.

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Before the classified tapes were forwarded to Statistics Canada in Ottawa for statistics generation, scattergrams for each tape were plotted using the number of pixels of a given crop in each segment (Y variable) versus the actual ground area of that crop in the same segment (X variable). A linear regression was run to insure that the classification was acceptable.

3. RESULTS

3.1 PRIMARY GOALS

As previously mentioned, cloud cover and the limitations of a biological window resulted in only 50% of the desired tapes being acquired. Three of the six Manitoba sub-provincial areas received full coverage. Table III contains results of the remote sensing project.

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Table III

Remote Sensing Results

Crops	Acres	C.V.
SPA 3 - Crop District 7*		
Canola-Rapeseed	145,056	8.5%
Cereal Grains	1,091,930	5.8%
Summerfallow	93,232	9.2%
SPA 4 - Crop District 8		
Canola-Rapeseed	185,467	8.5%
Cereal Grains	1,080,058	5.0%
Summerfallow	42,735	16.2%
SPA 5 - Crop Districts 9 and 10		

There were insufficient ground calibration points to generate accurate estimates for this SPA.

* One enumerative area south-west of Winnipeg was damaged by tornado, and therefore was omitted from the target area.

3.2 SECONDARY GOALS

The following summary describes the status of the project's secondary goals. Small area estimates at the crop district level were achieved

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in Crop Districts 7 and 8; however, the major impediment to obtaining rural municipality estimates is the large number of ground segments required for analysis. Even in SPA 5 there was a problem problem of ground data requirements. It was hoped that a CCRS, SC, MRSC land use study would provide supplementary ground data; however, the land categories were incompatible with those of the remote sensing project.

Other data sources (refer to section 5) are being studied to assess their effectiveness as alternate or supplementary sources of ground data.

Specialty crop tests are now being conducted at MRSC. Although identified as a secondary goal of this project, the specialty crop studies are using neither the imagery nor the ground data from the crop area project.

Thematic Mapper imagery of Crop District 7, and Manitoba Crop Insurance Corporation (MCIC) data on specialty crops are being used in this project. Although there is not enough data on all crops of interest to produce estimates, separability studies will be the first step towards operationalizing specialty crop work.

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Research into soil-related stratification was conducted during the project by adopting a Uniform Productivity Area (UPA) approach. Section 4 deals with this study and its applications.

4. CLASSIFICATION PERFORMANCE ASSESSMENT PROCEDURES/ UNIFORM PRODUCTIVITY AREAS

Many assessment procedures are used in an operational remote sensing survey (see Figure III). The classification performance assessment procedure used in this project was developed and implemented in Manitoba in 1984.

It is necessary in a large scale project, to have an indication of the accuracy of the classification over the whole LANDSAT frame. In particular, it is important to ensure that the entire frame is classified with the same accuracy; otherwise, ground/LANDSAT relationships will differ, giving erroneous estimates. Areas with different ground/LANDSAT relationships should be considered as independent populations and be subject to separate statistical analysis.

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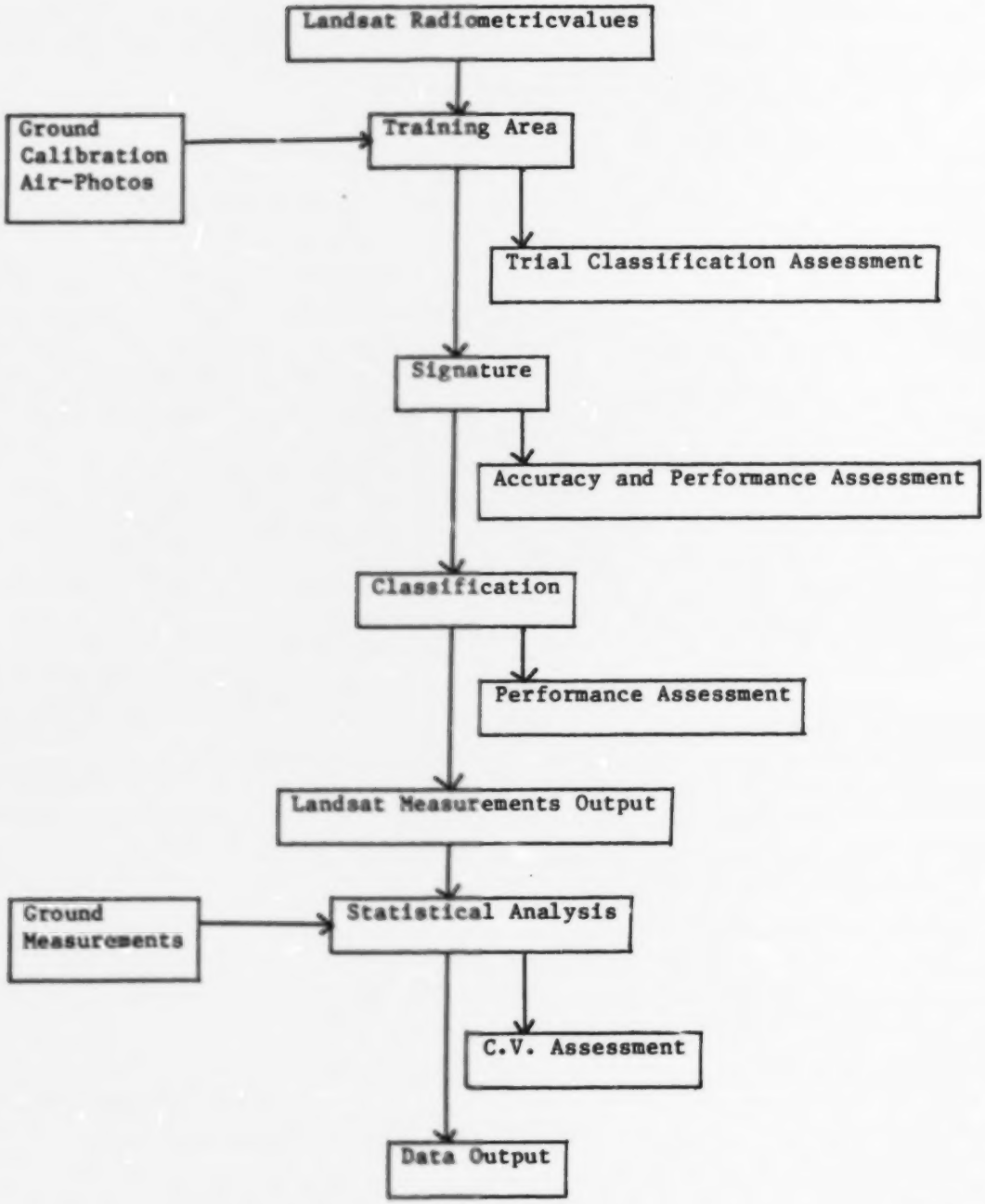
Figure III

Remote Sensing Survey Assessment



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Because soil development and genetic parent material are permanent features considered to affect the spectral reflectance of a crop, the uniform productivity area approach was adopted. These two characteristics were used to identify areas likely to exhibit homogeneity in spectral reflectance. After potential homogeneous areas were located on the imagery, enumerative area (EA) level measurements were captured and compared with the 1981 Census of Agriculture.

Table IV shows some results for canola/rapeseed. In Crop District 8, all of the homogeneous areas were classified within a narrow range. Other assessments confirm the results; a reasonable estimate for canola was generated in this crop district. No estimate was produced for Crop District 9, as there was a relatively large range of homogeneous areas. Area 4.1 provides an example of the problems encountered in this crop district. This area is mainly non-agricultural wetland and was virtually all classified as canola-rapeseed.

The classification performance assessment procedure has proven to be a useful tool for monitoring what is "happening" between the ground segments (for which we have information) and non-agricultural areas (where few sites are enumerated).

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The work of Remote Sensing Technical Team is continuing, and as Dr. A. Mack (Agriculture Canada) has stated, it will take a number of years of remote sensing data before we can identify with certainty truly homogeneous areas.

TABLE IV

Classification Performance Assessment: Some Results of the 1984 Manitoba Project

Canola/rapeseed

Crop District	Homogenous Area Number	Ratio*
8	1.0	.55
8	2.0	.45
8	3.1	.49
8	3.2	.62
8	3.3	.42
8	3.4	.70
8	4.1	.35
8	4.2	.40
8	5.0	.66
8	6.1	.57
8	6.2	.41
8	6.3	.14
8	7.0	.28
9	1.1	.66
9	1.2	.52
9	2.0	1.27
9	3.0	.78
9	4.1	6.88
9	6.0	1.50
9	7.0	.57
9	8.0	4.18
9	9.0	3.07

RATIO = number of acres at 1981 Census/number of pixels at current year at homegenous area level.

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5. POTENTIAL FOR NEW DATA SOURCES

A new data bank of ground reference information is being investigated with the aim of incorporating it into the crop area estimating program. The Manitoba Crop Insurance Corporation maintains a data bank of insured lands throughout agro-Manitoba. This data base contains specific information on location and crop type, date of seeding, fertilizer rates, etc. for approximately 60% of Manitoba lands under cultivation.

An agreement has been reached between the Corporation and the Remote Sensing Technical Team for access to this valuable data source. Currently the information is being tested to increase the density of segment data to the level required for small area estimates, especially at the municipal level. The current density of the NFS segments is inadequate to provide linear regression estimates for this purpose.

On a yearly basis, the data can concurrently be used in a "stand alone" form to provide extrapolated crop area estimates which can be compared to the rerote sensing derived figures.

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The present method of utilizing the data involves reading a computer tape set and sorting the data into legal land description files so that they may be located geographically on the LANDSAT image. To facilitate regression analysis, only complete quarter sections which are insured are examined. To integrate the crop insurance inform tion into the linear regression procedure for remote sensing, all fields selected must be manually identified and drawn onto the satellite image through interactive graphics. This is required so that pixel counts from the satellite estimate may be regressed against actual ground area values.

The manual drawing of the crop insurance fields on the satellite data would be an operational bottleneck when time is the essence of the entire project. Unlike the National Farm Survey, the problem is compounded when one considers the large turnover of fields being insured in terms of geographic position.

One way to alleviate the problem of manually drawing field boundaries would be to develop computer software to do this automatically. The procedure would require LANDSAT data to be geometrically corrected to a preferred pixel size of 50m. Within the province of Manitoba, a data base of Universal Transverse Mercator (U.T.M.) coordinates could

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be generated for all the section corners in the agricultural area. This data base could then be stored by legal description on the image analysis equipment. When LANDSAT data is geometrically corrected, the resulting raster data set is registered to the U.T.M. system.

The next phase would require a computer graphics program which would allow the analyst to key in required section numbers based on their legal description. Once keyed in, a computer program would connect the four U.T.M. coordinates of the respective section with displayed lines and save this file as a training area. This process would eliminate the time-consuming process of first locating and subsequently delineating these lines manually.

6. POTENTIAL FOR CANADA-WIDE CROP AREA ESTIMATES

6.1 THE CONCEPT

The concept of a Canada-wide and timely crop area estimate based on remote sensing methods has been proposed by Deloitte, Haskins and Sells Associates (1982). Their proposal centred around forming a centralized group to be called the Western Canada Crop Data Centre. The value of Canada-wide crop area estimates is well known to those in commodity exchanges, the Wheat Board and other agricultural industries. Knowledge of crop production is extremely beneficial when dealing in the competitive world grain market.

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This study has shown that with cooperation between the participating groups of Statistics Canada, Manitoba Department of Agriculture, and the Manitoba Remote Sensing Centre, crop area estimates at a Provincial level are indeed possible.

6.2 The Extension Proposal

For several years Statistics Canada has been actively participating in remote sensing crop estimates in New Brunswick and Prince Edward Island, canola-rapeseed in parts of Alberta and, more recently, canola-rapeseed/cereal grains/and summerfallow in Manitoba. These projects have been conducted in conjunction with the Canada Centre for Remote Sensing.

Since the inception of this program with CCRS, the first year of each project is carried out as a joint experimental pilot study. The second and third years involve an expansion of the project to allow staff of the user agency to integrate the technology into their regular on-going program.

As this program has developed, Statistics Canada has gained expertise in many facets; from developing sampling and stratification designs to adopting field procedures and performing satellite image processing.

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To proceed in the development of Canada-wide remote sensing crop area estimates, cooperation with the provinces is imperative. Experience gained in Manitoba has shown that significant benefit is derived when local image analysis staff perform the real-time LANDSAT classification. Local knowledge of crop development, crop distribution and the ease of locating parcels of land on the satellite image greatly speed up the classification process. These intrinsic benefits should not be overlooked in large scale remote sensing projects.

Statistics Canada, on the other hand, has a pool of statistical knowledge, trained methodologists and the necessary computer hardware and software to handle a wealth of crop area estimates. The logical route to follow would be first to conduct pilot projects within each Province on a scale such as that conducted in Manitoba. Initially real-time classification could be done jointly between Statistics Canada and the respective Provincial authority. During the following year, the Province could conduct the classification independantly, while Statistics Canada would provide "central-clearing-house" services for the statistical generation component.

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After the first large scale project is conducted in a Province, a follow-on project, during the next year, is relatively straightforward because the paramaters for the ordering of CCT's is the same and an archival tape set would be on hand for crop district boundaries, enumerative areas and National Farm Survey segments.

Presently, all the Western crop producing provinces along with Ontario have locally based image analysis hardware which would permit such a program to become operational. In addition, Statistics Canada has recently acquired an image analysis work station which will greatly enhance its ability to interface with other supporting agencies.

7. CONCLUSIONS

The results of the 1984 project are encouraging. Although cloud cover and lack of ground data posed some problems it is evident that a full-province project is feasible. Cooperation and automation are the keys to success in large-area estimation.

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8. REFERENCES

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